Seismic Monitoring of the Shumagin Seismic Gap, Alaska

14-08-0001-A0616

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Nontechnical Summary

The Shumagin Seismic Network is operated to monitor seismicity in the Shumagin Seismic Gap and adjoining regions. The Shumagin Gap is a section of the Alaska-Aleutian subduction zone where a large earthquake is expected. It is also one of the few places where on-land seismometers can be placed directly over a subduction-zone thrust, so provides a natural laboratory for studying the generation of great earthquakes. The network provides earthquake locations, magnitudes, and digital waveform data that is used in studies of regional tectonics, analysis of possible earthquake precursors, and seismic hazard evaluation.

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Investigations

Seismic data from the Shumagin seismic network were collected and processed to obtain digital waveforms, origin times, hypocenters, and magnitudes for local and regional earthquakes. The data are used for earthquake source characterization, determination of earth structure, studies of regional tectonics, analysis of possible earthquake precursors, and seismic hazard evaluation. Yearly bulletins are available starting in 1984.

Results

The USGS decided in early 1991 to cease support for Aleutian network operations. Accordingly, all remote stations in the Shumagin Seismic Gap were removed during the 1991 field season and network operations ceased at that time. Only one high-gain station remains, the broad-band station in Sand Point, which was moved to a new, quieter site on land owned by the Sand Point School (informally referred to as SPS). In addition to this station, digital strong-motion instruments continue to be operated by Lamont in Sand Point and Dutch Harbor, and analog strong-motion instruments were left at four remote sites in the Outer Shumagins (BKJ, CNB, NGI, and SIM). Thus, the 1991 field season marks the end of eighteen years of near-continuous monitoring of the Shumagin Seismic gap. Following removal of USGS-supported networks, the entire Aleutian arc is monitored by three stations east of Kodiak (~2500 km of plate boundary): SDN, 160.5°W; ADK, 176.5°W; and SMY, 174°E.

Shumagin network data were used to locate 121 earthquakes from January 1 to June 30, 1991, bringing the total number of digitally recorded events in Shumagin network catalog to 5926 since 1982. As the network was removed in the summer of 1991 (telemetry ceased on June 28), no further event locations from this project are anticipated. This number is somewhat lower than in previous years, because a substantial part of the network was removed in the summer of 1990. The seismicity for the first half of 1991 is shown in map view on Figure 1 and in cross section on Figure 2. Events shown by solid symbols are those events that meet the following quality criteria: located by 8 or more *P* or *S* arrivals, vertical error from *Hypoinverse* less than 10 km, and horizontal error less than 5 km. The same criteria were used for the comparison with the PDE catalog, discussed below (Figure 3). Other events are shown by open symbols. These criteria provide a rough indication of the location quality, and show that epicenters more than 100 km from the nearest station are rarely well determined. Additional numerical tests of hypocenter stability show that when the entire network is operating, shallow events west of 166°W, east of 156°W, or seaward of the trench can not be reliably located. Also, depths of shallow earthquakes are only well-determined beneath the Shumagin Islands.

The overall pattern in Figures 1-2 resembles the long term seismicity. Seismicity is concentrated near the base of the main thrust zone between 25 and 40 km depth, and immediately above it within the overriding plate. Seismicity contours below 30 km depth parallel the volcanic arc, rather than the trench, and become closer to the trench west of the network (Figure 1). Seismicity appears to be sparse where the main thrust zone is shallower than 35 km, between the Shumagin Islands and the trench. Deeper seismicity extends to depths of 200 km. Some locations near 100 km depth on Figure 2 correlate with the lower plane of the double seismic zone seen in long-term seismicity.

The most significant activity in the Shumagin area was a M_S = 6.7 event on May 30, 1991. The event was located in the Sanak basin, in a region characterized by persistent localized low-level seismicity; this cluster has been evident throughout the period of network operations. The May 30 event was determined to have a shallow thrust mechanism from teleseismic body-wave inversion, at a depth of 30±5 km. The mechanism, depth, and location are all consistent with this earthqake being due to thrusting on the main plate interface. The surface-wave magnitude (6.7) formally makes this event the largest to have been recorded in the Shumagin region since the advent of regional monitoring in 1973, although the event is not significantly larger than M_S = 6.5-6.6 events in 1983, 1985, and 1987, and is significantly smaller than major regional events of 1917 (M_S = 7.4), 1946 (M_S = 7.4), and 1948 (M_S = 7.5).

Three primary tasks were accomplished in the Summer 1991 field season. First, all telemetered equipment was removed and remote sites (all in wildlife refuges) were cleaned up. The only exceptions are the four analog strong-motion recorders (SMA-1's) mentioned above, and physical structures for 4 sites near volcanoes left for the Alaska Volcano Observatory. Second, locations were redetermined using GPS surveying equipment at all sites not previously removed (Table 1). All locations are single-station 3D locations made with Trimble recorders made while Selective Availability was turned off. Differences with previous locations were a few to a couple tens of meters at most, except for one site (BKJ) whose previous location was in error by ~600 m.

The third significant accomplishment of the 1991 field season was the successful moving of the Sand Point broad-band station to a new, quiet site at the town school (SPS). The Guralp CMG-4 sensors were placed a pier poured directly on bedrock, enclosed in a small, low structure. Recording is done continuously at the school on a Sun-based system, where data is available via modem for up to one week. After that, data is written to tape and mailed to Lamont. Broad-band data is digitized at two gains at 20 samples per second, 12 bit samples, producing 6 continuous records. The local school district plays an active role in station operations. The station would make a good site for National Network deployment in the Aleutians. This instrument has provided high-quality records since late July, 1990 when it was configured in this mode at the old Sand Point station, and provides data that are being used for detailed source and propagation studies.

Now that future monitoring will be done solely by teleseismic recording, it is worthwhile to assess differences between local and teleseismic locations. We have correlated the Shumagin catalog with the PDE catalog from 1982 to 1990 (Figure 3; see caption for details). The most significant differences are a location bias and a magnitude bias. PDE locations are systematically located arcward relative to Shumagin Network locations, probably because of the high-velocity downgoing slab. Events beneath the Shumagin Islands (159°W - 161°W) are located to within a few km by the local network; here PDE locations are 25-50 km closer to the arc. Events lower in the slab (near 56°N) and farther from the network show larger biasses (40-100 km). Location biasses for earthquakes directly beneath the Shumagin Islands are probably most reflective of systematic errors in teleseismic locations, rather than in Network locations, and indicate that teleseismic locations cannot be relied upon to better than 25-50 km. These biasses are generally attributed to the effect of the high-velocity slab on travel times.

The Shumagin magnitudes are systematically lower than the PDE magnitudes, by 0-1 units but with significant scatter. Shumagin magnitudes are based upon maximium peak-to-peak amplitudes in the early part of the *P* wavetrain, corrected for the instrument response at the dominant frequency. It is not known what causes this discrepancy, but we suspect that it may be due to scale saturation for Shumagin stations above magnitude 4; for these events the high-gain stations are on scale but the *P* wavetrain shows significant energy over several cycles. The high-gain channels are off-scale for larger events, and Shumagin magnitudes are based upon other measurements.

TABLE 1. Shumagin Seismic Network, Stations 1982-1991

Station	Latitude	Longitude	Elev. (m)	Method	Instruments
bal	55°11.60'N	162°47.21'W	366		SPZ
bkj	55°09.64'N	159°33.99'W	170	GPS	SPZ,SMA
blh	55°42.15'N	162°03.95'W	390		SP3
cdb	55°11.50'N	162°42.00'W	25		SMA
cnb/cnf	54°49.22'N	159°35.37'W	100	GPS	SP3;FBA;SMA
dlg	55°08.39'N	161°50.15'W	350	GPS	SPZ;SMA
drr	54°55.44'N	162°17.07'W	390	GPS	SPZ;SMA
dutf	53°54.00'N	166°32.00'W	25		SSA
fsp	54°56.44'N	163°27.72'W	275		SPZ
ivf	55°53.75'N	159°31.80'W	275		SPZ;SMA
ngi	55°02.37'N	160°04.18'W	270	GPS	SPZ;SMA
pn6	55°27.12'N	161°54.89'W	814		SPZ
pn8	55°26.62'N	162°01.25'W	605		SPZ
ps1	55°25.41'N	161°44.20'W	300	GPS(2D)	SPZ
ps4	55°21.23'N	161°52.12'W	560	GPS	SPZ
pvv	55°22.45'N	161°47.45'W	180	GPS	SP3
sas/sai	55°20.36'N	160°29.91'W	23	GPS	SP3;BB;SSA
sps	55°21.05'N	160°28.48'W	90	GPS	BB
sgb	55°32.76'N	160°27.30'W	290	GPS	SP3;SMA
sim	55°55.20'N	159°15.50'W	500		SMA
snk	54°28.44'N	162°46.52'W	159		SPZ;SMA
sqf/sqh	55°13.23'N	160°33.86'W	310	GPS	FBA
dt2	55°09.91'N	162°13.83'W	660	(AVO Station)	SPZ
zkb	55°19.16'N	160°45.08'W	250	GPS	SPZ

Instruments: SPZ, short-period vertical velocity sensor (Geospace HS-10, 1 Hz); SP3, short-period 3-component sensors (Geospace HS-10, 1 Hz); SMA, analog strong-motion accelerometer (Kinemetrics SMA-1); FBA, telemetered 3-component force-balance accelerometer (Kinemetrics FBA-3/FBA-13); SSA, digital srong-motion accelerometer (Kinemetrics SSA-1); BB, 3-component broad-band (Guralp CMG-4; 0.05 Hz corner). Underlined instruments remain deployed as of July, 1991.

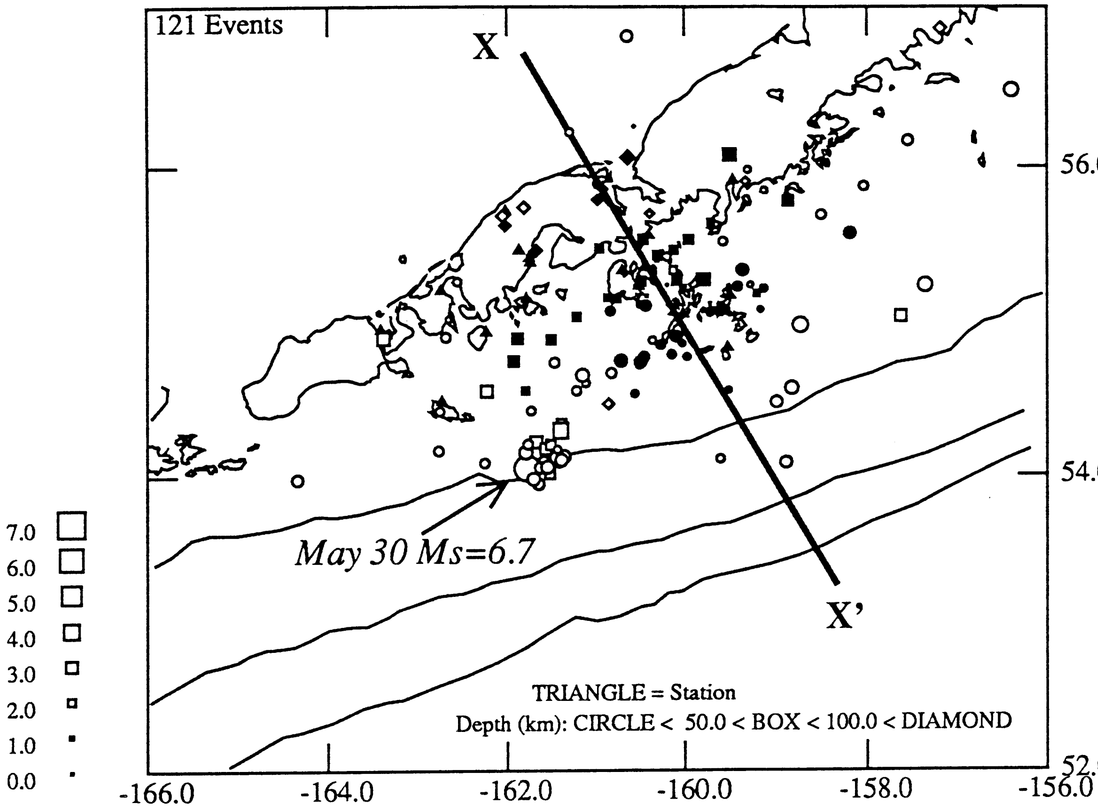

Figure 1. Map of seismicity located by the Shumagin seismic network from January to June, 1991. Symbol shapes show depths, sizes show magnitudes. Filled symbols meet criteria for well-located events, described in text.

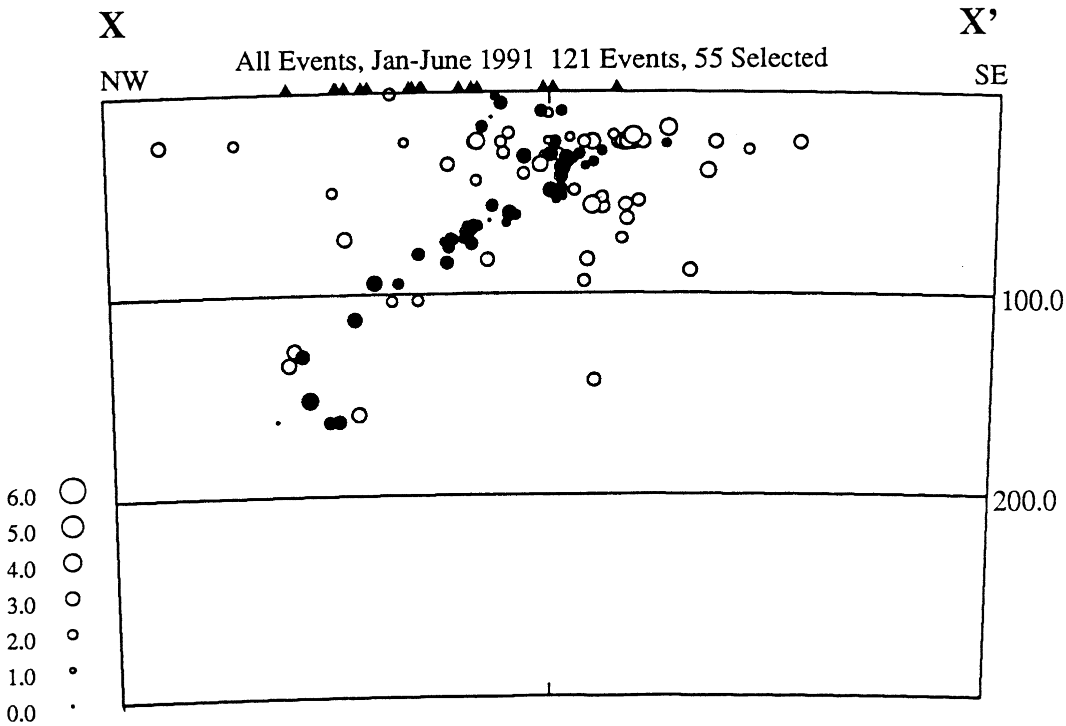

Figure 2. Cross-section of all Shumagin Network seismicity January to June, 1991, located in Figure 1. Triangles are station locations.

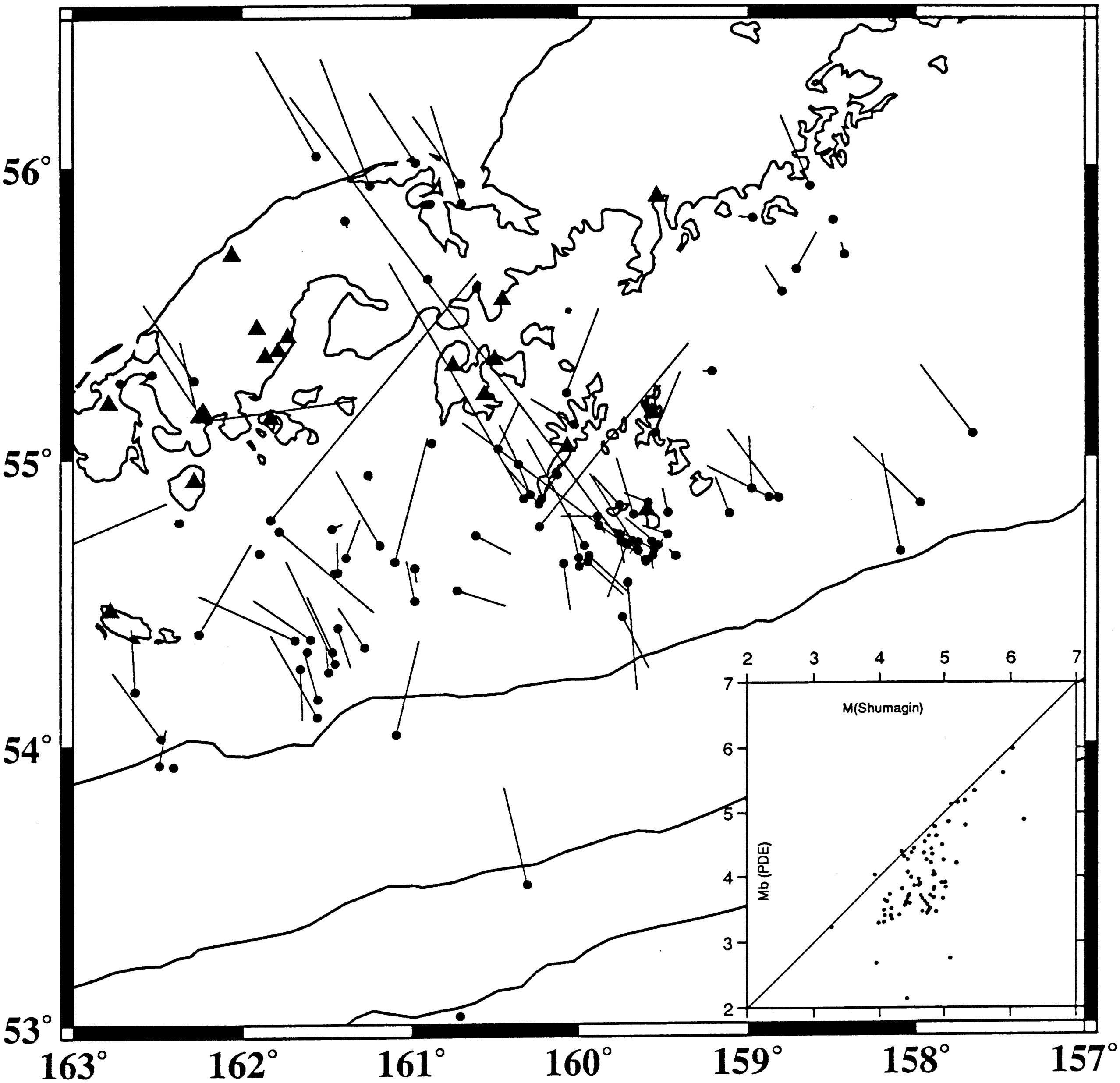

Figure 3. Comparison of Shumagin catalog data, 1982-1990, with the PDE catalog. A total of 260 matching events are found with PDE locations between 164°W and 204°W, of which 120 have Network locations that meet the quality criteria discussed in text. Only these 120 events are plotted, and the subset of these with magnitudes is shown in the inset. Solid circles are Network locations, vector tips are PDE locations. Triangles are Network stations. Inset shows comparison of body wave magnitudes between Shumagin catalog and PDE (each magnitude is randomly perturbed by up to 0.05 units, for display purposes).